Assessment and Management of Transportation Infrastructure Security using the Inoperability Input-Output Model (IIM)

Yacov Y. Haimes
Center for Risk Management of Engineering Systems
University of Virginia

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Acknowledgements

Gary Allen
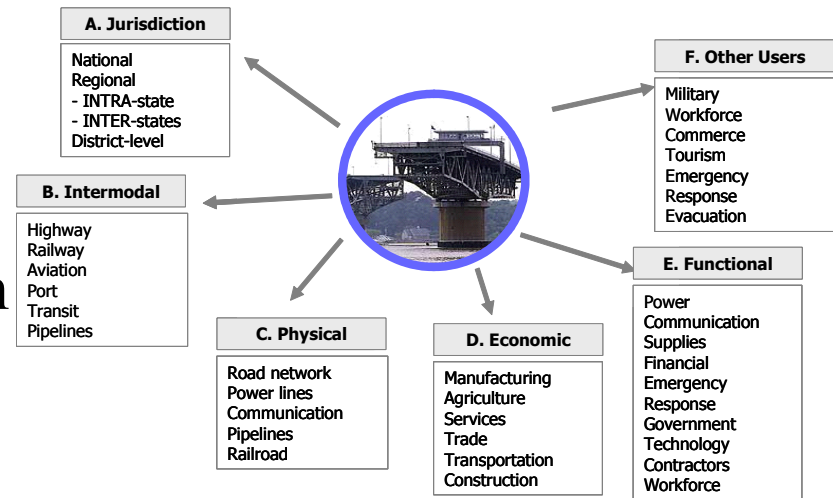
Wayne Ferguson

George Foresman

Jim Keck

Steve Mondul

Transportation Interdependencies

- The transportation infrastructure is designed to **support other infrastructures and systems** around it; thus it is inherently depended upon and dependent on many other infrastructures.

- **Economic recovery** after a major incident is closely tied with transportation as it enables **workers** to go back to their jobs, and commodities to be delivered.

A. Jurisdiction

National
Regional
- INTRA-state
- INTER-states
District-level

B. Intermodal

Highway
Railway
Aviation
Port
Transit
Pipelines

C. Physical

Road network
Power lines
Communication
Pipelines
Railroad

D. Economic

Manufacturing
Agriculture
Services
Trade
Transportation
Construction

E. Functional

Power
Communication
Supplies
Financial
Emergency
Response
Government
Technology
Contractors
Workforce

F. Other Users

Military
Workforce
Commerce
Tourism
Emergency
Response
Evacuation

Examples of Interdependencies:

- **Geographical/Jurisdictional**

- **Economic**

- **Intermodal**

- **Other Users**

The Message of this Presentation

Impress on you the **importance** and **impact** of **infrastructure interdependencies** on:

- **Virginia's economy**

- **Recovery time** following an incident

- Setting **recovery priorities** through quantitative trade-offs

- The **efficacy of risk management** (cost-benefit-risk **with** and **without** risk management)

Inoperability Input-Output Model (IIM) for Modeling Interdependencies

- The Inoperability Input-Output Model (**IIM**) developed by the University of Virginia's Center for Risk Management of Engineering Systems is based on the economic model developed by **Wassily Leontief, for which he received the Nobel Prize in Economics in 1973.**

- The **IIM provides decisionmakers with a tool** for systemically **prioritizing economically critical sectors** and identifies those sectors whose **continued operability is critical during recovery operations.**

Bureau of Economic Analysis (BEA) Database

- Economic data from the Bureau of Economic Analysis (**BEA**) constitute the foundation of the **IIM.**

- BEA publishes I-O data of the entire U.S. Economy.
  - **$80+ million annual budget.**
  - Actual data from Census records.
    - Regional, State, National, International Data
    - Output, prices, employment, commodity use and manufacturing etc…

Deployment of the IIM

- Defense Threat Reduction Agency (**DTRA**): Impact on the Northern Command, Colorado Springs

- **Commission** on High Altitude Electro-Magnetic Pulse (**EMP**) Attacks Against the United States

- Department of Homeland Security (**DHS**): Exercise for Sub-Cabinet-Level Officials

- **VDOT-VTRC** (On-Going Project)

Databases Used for the Transportation Interdependency Analysis

TRANSPORTATION ASSET FAILURE:

- Closure
- Congestion
- Collapse

IMPACT:

(1) Workforce Commute
Losses from
Delayed/Absent Workers
Bureau of Labor Statistics

(2) Commodity Flow
Losses from
Delayed Commodities
Bureau of Transportation Statistics

(3) Business Accessibility
Losses from Business
Demand Reduction
Bureau of Economic Analysis

DATABASES:

- Journey to Work Data
- Regional Employment Data
- Regional Earnings Data
- Commodity Flow (CF) Data to Destination
- CF Data from Origin
- CF Data through Corridors
- RIMS II Data
- Geographic Location Data

IIM Case Study A:
Transportation and Utility Sector Supply Scenario

- Transportation sector comprises of various modes (e.g., transit, trucking, water, air, etc.)
- The utility sector comprises of electric services, natural gas transportation, natural gas distribution, water supply and sewerage systems, sanitary services, steam supply, and irrigation systems
- The annual gross output of transportation and utility sectors in Virginia were approximately $17B and $7.5B, respectively based on year 2000 data

- **Consider a simultaneous 10% perturbation to the transportation and utility sectors in Virginia**

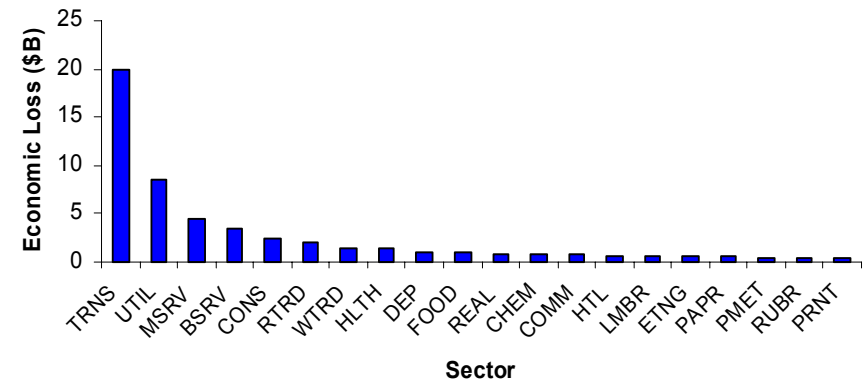# IIM Case Study A:
Economic Loss and Inoperability Rankings

Scenario: **10% Perturbation** to VA transportation and utility sectors

Top-20 Affected Sectors in Terms of Inoperability Impact

Top-20 Affected Sectors in Terms of Economic Loss Impact

TRNS	Transportation
UTIL	Electric, gas, and sanitary services
STNE	Stone, clay, and glass products
PMET	Primary metal industries
PAPR	Paper and allied products
CHEM	Chemicals and allied products and petroleum and coal products
MIN	Metal mining and nonmetallic minerals, except fuels
RUBR	Rubber and miscellaneous plastic products and leather and leather products
COAL	Coal mining
TEXT	Textile mill products

TRNS	Transportation
UTIL	Electric, gas, and sanitary services
MSRV	Miscellaneous services
BSRV	Business services
CONS	Construction
RTRD	Retail trade
WTRD	Wholesale trade
HLTH	Health services
DEP	Depository and nondepository institutions and security and commodity brokers
FOOD	Food and kindred products and tobacco products

IIM Case Study A:
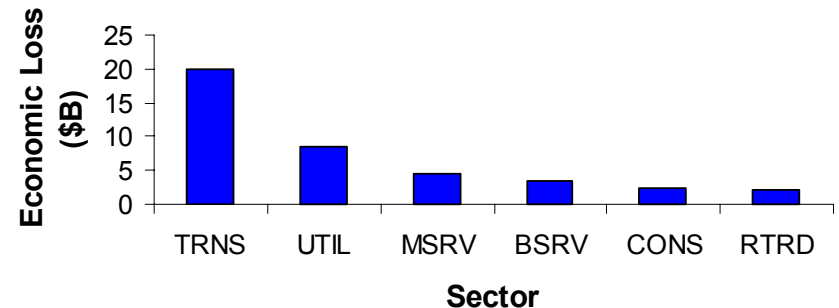# Economic Loss and Inoperability Rankings

Scenario: **10% Perturbation** to VA transportation and utility sector

Top-5 Affected Sectors in Terms of Inoperability Impact
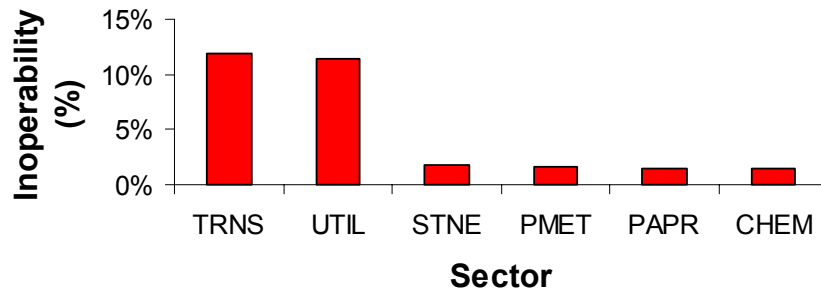
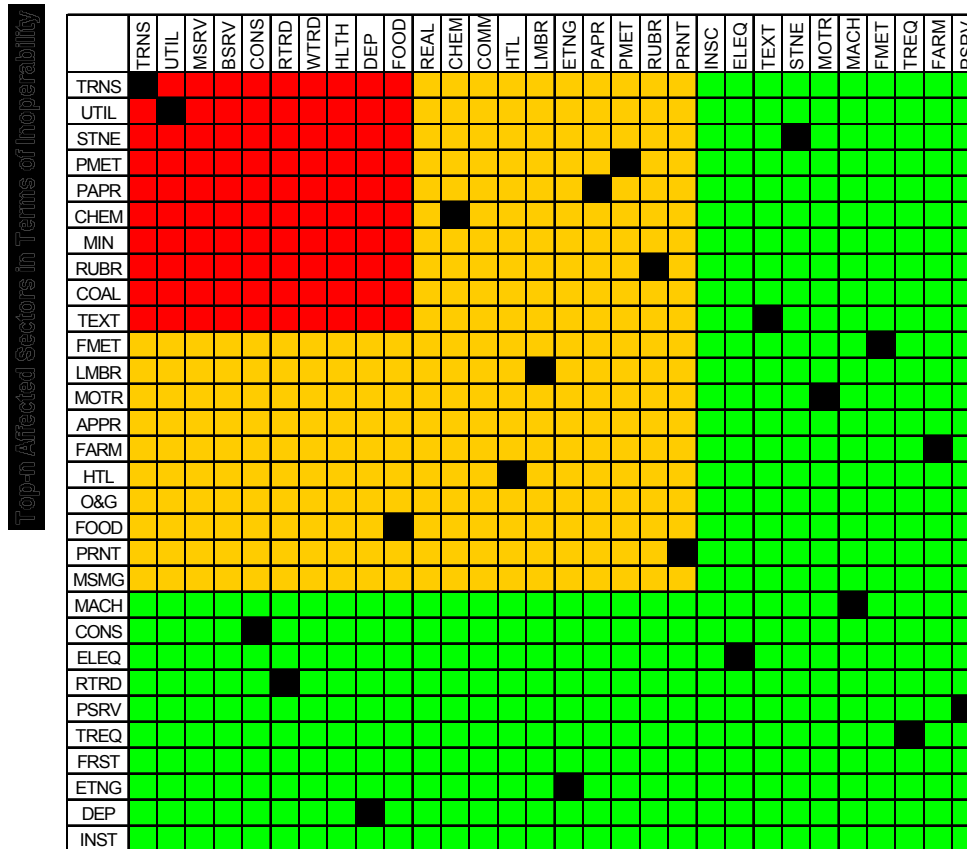| TRNS	Transportation
UTIL	Electric, gas, and sanitary services
STNE	Stone, clay, and glass products
PMET	Primary metal industries
PAPR	Paper and allied products
CHEM	Chemicals and allied products and petroleum and coal products

Top-20 Affected Sectors in Terms of Economic Loss Impact

TRNS	Transportation
UTIL	Electric, gas, and sanitary services
MSRV	Miscellaneous services
BSRV	Business services
CONS	Construction
RTRD	Retail trade

IIM Case Study A:
Sector Impact Evaluation Matrix

Top-n Affected Sectors in Terms of Economic Losses

Scenario:
10% Perturbation to VA transportation and utility sectors

Legend:
- 🟥 Top-10 Zone
- 🟧 Top-20 Zone
- 🟩 Top-30 Zone

IIM Case Study A:
Sector Impact Evaluation Matrix

Most Affected Sectors in Terms of Economic Loss

Scenario:
10% Perturbation to VA transportation and utility sectors

Legend:
- 🟥 Top-10 Zone
- 🟧 Top-20 Zone

IIM Case Study A:
Temporal Sensitivity Analysis (10% Perturbation)

Sample Interpretations:

Reducing transportation sector's time to recovery by 3 days or utility sector's time to recovery by 12 days will result in a $100M economic loss reduction.

Reducing transportation sector's time to recovery by 10 days or utility sector's time to recovery by 3 days will result in a $100M economic loss reduction.

Iso-Economic Loss Contours

Legend:
$800M
$700M

Time To Recovery of Utility Sector (days)

Time To Recovery of Transportation Sector (days)

IIM Case Study B: Workforce-IIM Analysis

- Consider a scenario where both **Hampton Roads Bridge-Tunnel** and **Monitor-Merrimac Bridge-Tunnel** will be closed to traffic

Northwest Region:
- Essex
- Gloucester
- Hampton (city)
- James City & Williamsburg
- King and Queen
- King William
- Mathews
- Middlesex
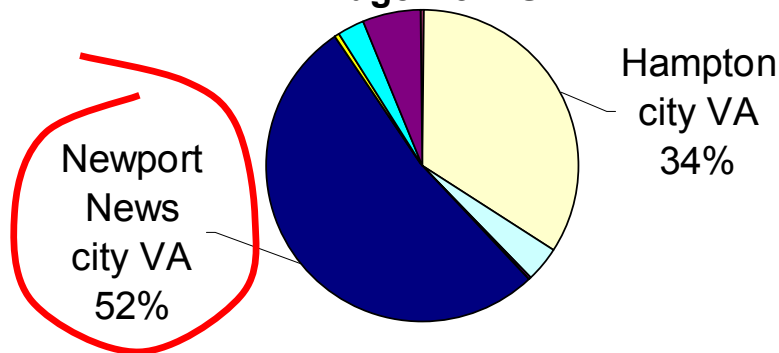- Newport News (city)
- York & Poquoson

Southeast Region:
- Accomack
- Chesapeake (city)
- Greensville & Emporia
- Isle of Wight
- Norfolk (city)
- Northampton
- Portsmouth (city)
- Southampton & Franklin
- Suffolk (city)
- Surry
- Sussex
- Virginia Beach (city)

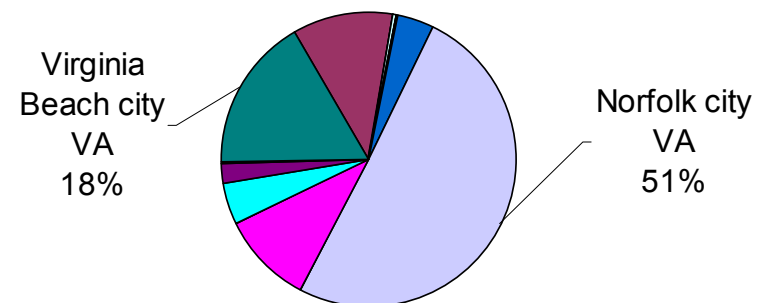# IIM Case Study B:
Journey to Work Data

From	To NW	To SE	Totals
NW	214,952	22,658	250,705
SE	22,410	534,551	571,822
To Totals	247,348	563,811	3,164,052

Destination of Workers Crossing Bridge from SE

Hampton city VA 34%

Newport News city VA 52%

Destination of Workers Crossing Bridge from NW
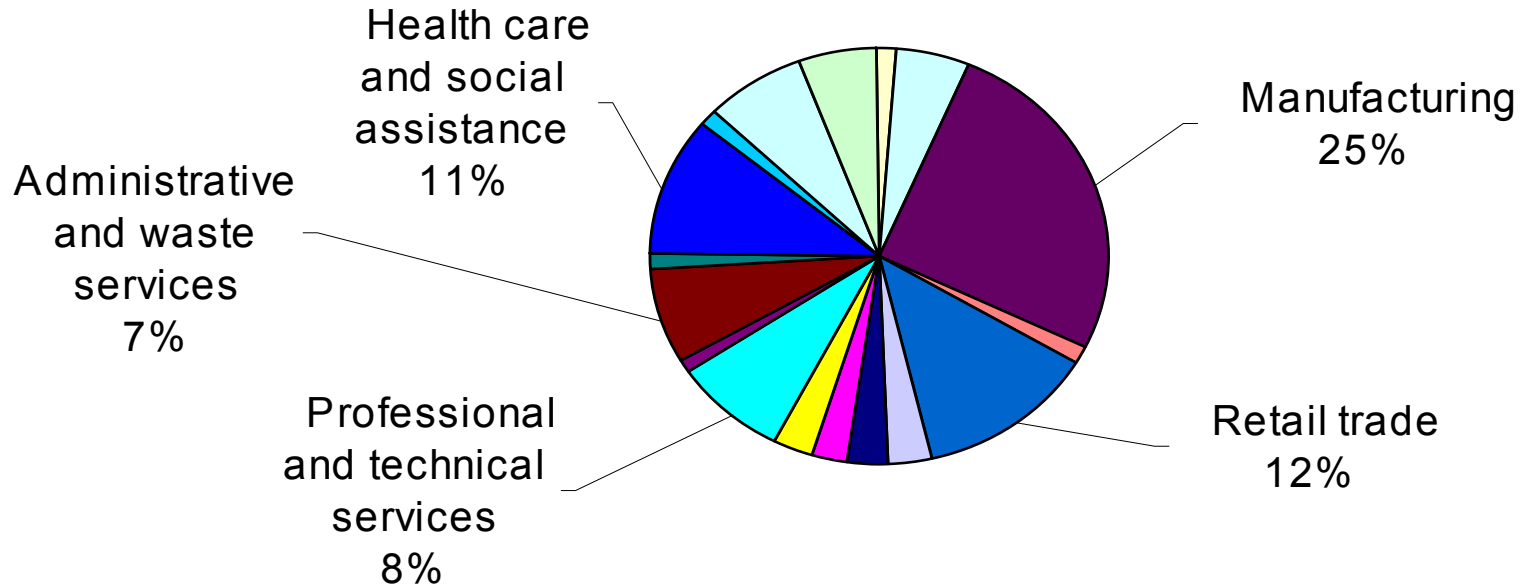
Virginia Beach city VA 18%

Norfolk city VA 51%

IIM Case Study B: Workforce-IIM Analysis Using Employment Data (BEA)

Distribution of Workers in Newport News (12,000 across river)

Health care and social assistance 11%

Administrative and waste services 7%

Professional and technical services 8%

Manufacturing 25%

Retail trade 12%

IIM Case Study B:
Economic Loss and Inoperability Rankings

Top-20 Affected Sectors in Terms of Inoperability
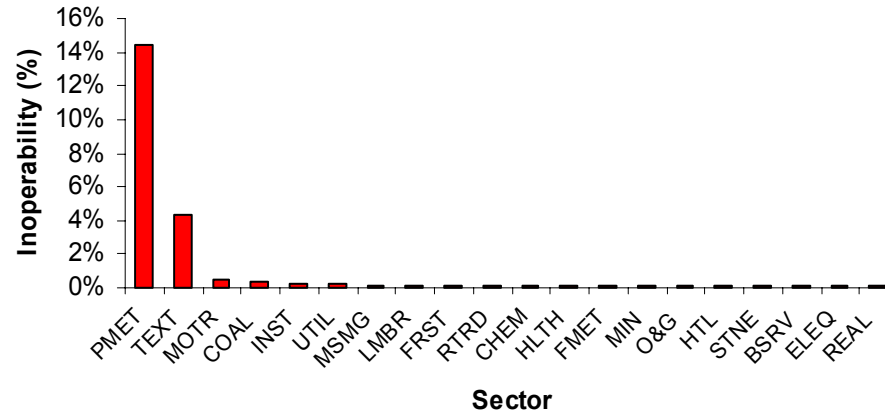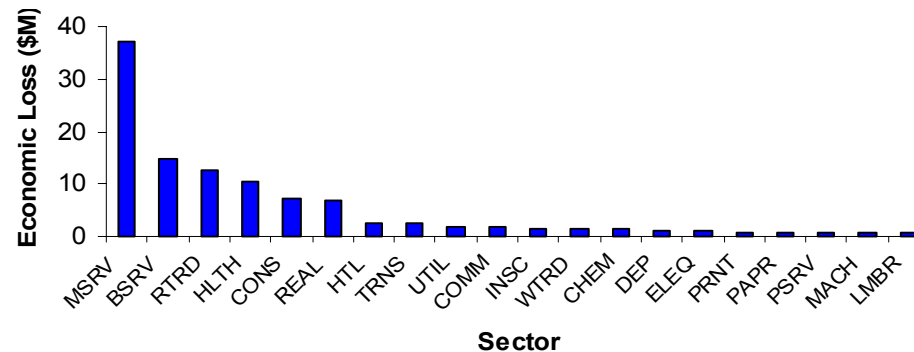

Top-20 Affected Sectors in Terms of Economic

IIM Case Study B:
Economic Loss and Inoperability Rankings

Top-20 Affected Sectors in Terms of Inoperability

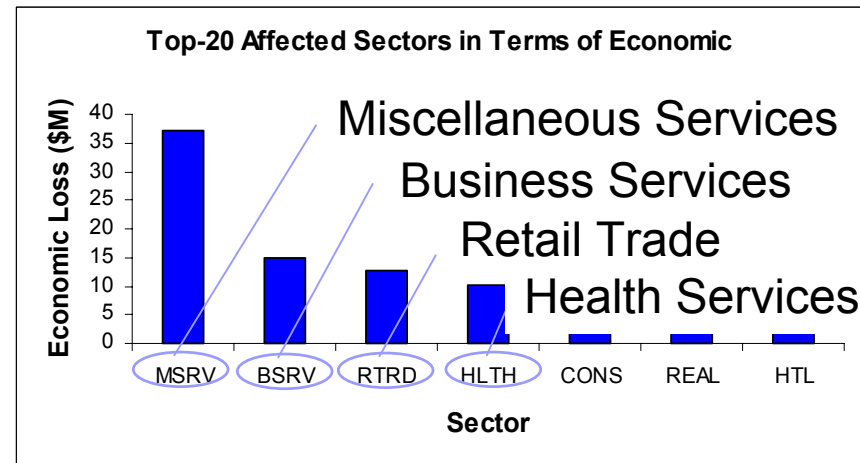Primary Metals Industries
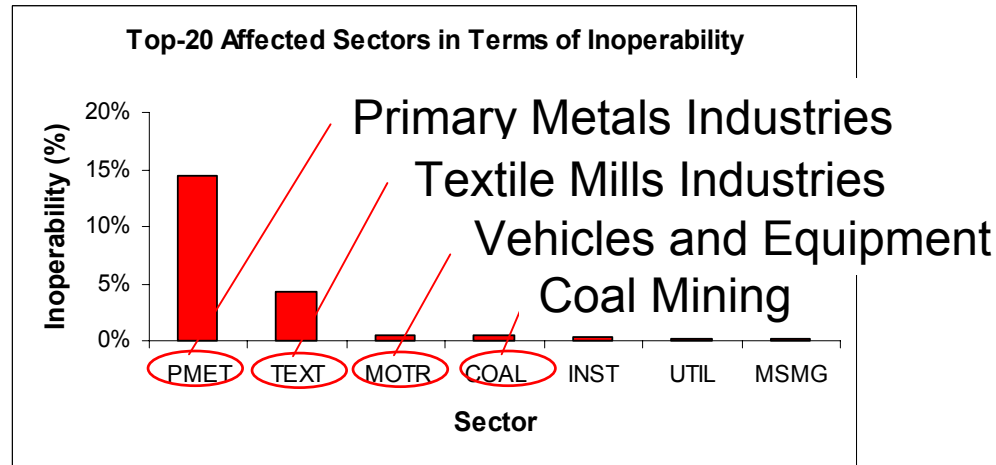Textile Mills Industries
Vehicles and Equipment
Coal Mining

PMET TEXT MOTR COAL INST UTIL MSMG

Top-20 Affected Sectors in Terms of Economic

Miscellaneous Services
Business Services
Retail Trade
Health Services

MSRV BSRV RTRD HLTH CONS REAL HTL

Summary

- There is a need to better manage the **risks of interdependencies** of the transportation infrastructure

- The **impacts** of transportation failure include:

    - Delay in **workforce commute**

    - Delay in **commodity flow**

    - Loss of business accessibility (or **demand reduction**)

    - Impact on **other infrastructures** (electric power, communications, etc.).

- The **IIM** can analyze and quantify impacts of transportation failures on interdependent sectors

Questions that Can Be Answered by the IIM

- What are the **economic and inoperability impacts** of a terrorist attack on Virginia's economy (or on the national economy)?

- What is **efficacy of risk management**? How can the private sector justify investments in security measures?

- What is the most effective cost-benefit-risk policy for **priority resource allocation** in the recovery?

- What **strategic security measures** in countering terrorism should be followed today in order to minimize future adverse effects?